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Apparatus for g nerating and deflecting a plasma jet

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Abstract

PCT No. PCT/US97/09252 Sec. 371 Date Nov. 25, 1998 Sec. 102(e) Date Nov. 25, 1998 PCT Filed May 30, 1997 PCT Pub. No. WO97/46056 PCT Pub. Date Dec. 4, 1997A plasma jet generator apparatus enabling effective deflection of the generated plasma jet is described. The apparatus has an electrode chamber having a gas inlet and an outlet and an electrode positioned therein defining an electrode axis. A pair of magnetic deflection systems for deflecting the direction of the plasma flowing from the electrode axis are provided. The magnetic deflection systems are formed from pole pairs which are distributed about the electrode axis such that two magnetic fields that are substantially perpendicular to each other can be generated to deflect the plasma away from the electrode axis.

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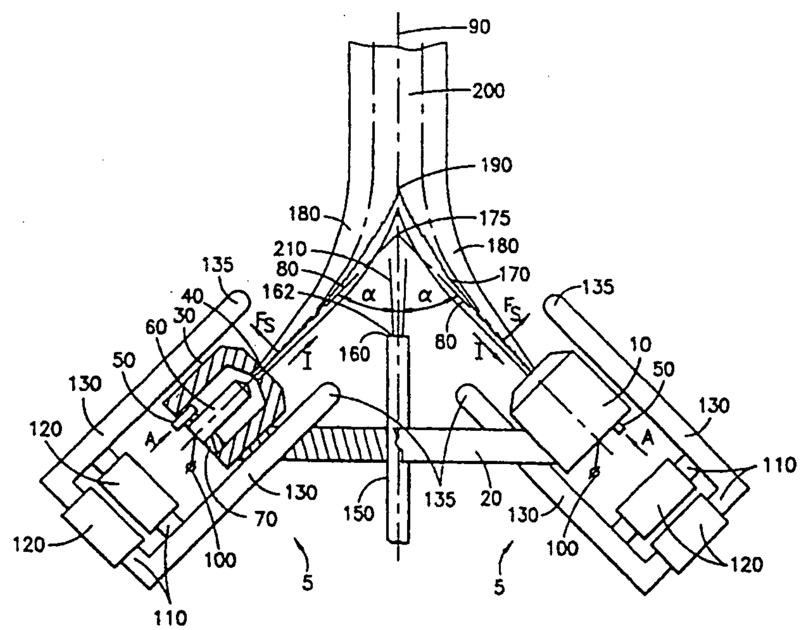


(57) Abstract

A plasma jet generator apparatus enabling effective deflection of the generated plasma jet is described. The apparatus has an electrode chamber having a gas inlet and an outlet and an electrode positioned therein defining an electrode axis. A pair of magnetic deflection systems for deflecting the direction of a plasma flowing from the electrode chamber outlet relative to the electrode axis is provided. The magnetic deflecting systems are formed from U-shaped members and are distributed about the electrode chamber. The magnetic deflecting systems enable two deflecting forces to be applied to the plasma so as to deflect the plasma away from the electrode axis.

APPARATUS FOR GENERATING AND DEFLECTING A PLASMA JET

BACKGROUND

Field of the Invention

The present invention relates to the plasma processing of substrates. More particularly, the present invention relates to an apparatus for generating and deflecting a plasma jet for treating substrates using a plasma jet treatment process.

Description of the Prior Art

Published application No. PCT/SU90/00286 describes a method for plasma processing of a material consisting of a system of more than two meeting plasma jets which form a mixing zone wherein a material to be processed is fed into the mixing zone. Direct electric currents are passed through sections of the plasma jets up to the mixing zone and a magnetic field is applied to the current conducting sections of each plasma jet. The apparatus for plasma processing of material described in the application comprises a charge conduit, an electric arc plasma jet generator further comprising a plurality of electrode units for generating the plasma jets. The electrode units are oriented at acute angles to an axis of the charge conduit and are connected to a direct current source. The apparatus further comprises a magnetic system formed from an open magnetic circuit with poles located in a mixing zone of the plasma jets. The apparatus described in PCT/SU90/00286 has very limited abilities to control direction of each plasma jet independently so as to control the structure of combined plasma flow, because the external magnetic field only allows changes to the distance between the plasma jet and combined plasma flow axis without correction of the plasma jet orientation in other directions.

Published application No. PCT/SU90/00287 describes an apparatus for plasma-arc processing of material. The apparatus comprises a charge conduit which is surrounded by a plurality of electric arc plasma jet generators and a magnetic system. The generators comprise two electrode assemblies. Solenoids are mounted on poles of the magnetic circuit. The apparatus can be used only if the plasma jets are directed towards the axis of

the apparatus with angles more than 45 degrees. If the angles are less than 45 degrees then the magnetic system itself causes instability in each of the plasma jets and the combined plasma flow. Another disadvantage is that each plasma jet orientation can be controlled only when it is located in equilibrium position within a narrow zone near the corresponding basic plane where both a second and third magnetic field interacts with it. If the plasma jet is deflected relatively far from the basic plane then the effectiveness of the control significantly reduces because only one of these magnetic fields interact with the plasma jet.

In published Russian Patent No. 2032281, a method and apparatus for plasma flow production is described. Plasma jets are formed by any method and are directed symmetrically to the axis of a common plasma flow at an angle less than 45 degrees. Direct current is passed along each plasma jet in opposite directions relative to the common axis and external magnetic fields are applied to each jet. The 1st magnetic field is applied between the axis (4) of each jet and the common axis, while the 2nd and 3rd fields are applied to the half-spaces between the axes. Interaction of the magnetic fields and the current in the jet causes deflection of the jets from their axes (2). The induction of the fields are adjusted, to ensure the axis (4) of the jets are parallel to the common axis after interaction and the configuration of the external magnetic fields is selected to increase the stability of the plasma jets. During random slight displacements of the jets, inductance to one side increases and decreases to the other side, to ensure return of the axis of the jet to a direction parallel to the common axis. The disadvantage of the above described method and apparatus is that the method can be realized and correspondingly the device can be used only if the plasma jets are directed to the device axis with angles less than 45 degrees. If the angles are more than 45 degrees then the magnetic system itself induces instability of every plasma jet and the combined plasma flow. Another disadvantage is that each plasma jet orientation can be controlled only when it is located in an equilibrium position within narrow zone near the corresponding basic plane where both second and third magnetic fields interact with it. If the plasma jet is deflected relatively far from the basic plane, then the effectiveness of the control significantly reduces because of only one of these magnetic fields interacts with the plasma jet.

SUMMARY OF THE INVENTION

The apparatus of the present invention enables effective deflection of the direction of a plasma jet. The apparatus for generating and deflecting the plasma jet comprises an electrode chamber having a gas inlet and an outlet. An electrode is positioned within the electrode chamber. The electrode defines an electrode axis. The generator is provided with a first magnetic deflection system for applying a first deflecting force to a plasma flowing from the electrode chamber outlet so as to cause the plasma to deflect away from the electrode axis in a first direction relative to the electrode axis. The first magnetic deflection system comprises a first U-shaped member formed from a first base and a first pair of poles having ends and a first coil positioned about the base. The first magnetic deflection system is positioned about the electrode chamber so that the first poles are on opposite sides of the electrode axis defined by the electrode positioned within the electrode chamber. The generator is also provided with a second magnetic deflection system for applying a second deflecting force to the plasma flowing from the electrode chamber outlet so as to cause the plasma to deflect away from the electrode axis in a second direction relative to the electrode axis. The second magnetic deflection system comprises a second U-shaped member formed from a second base and a second pair of poles having ends and a coil positioned about the base. The second magnetic deflection system is positioned about the electrode chamber so that the second poles are on opposite sides of the electrode axis defined by the electrode positioned within the electrode chamber. The first and second magnetic deflection systems enable the plasma jet to be deflected away from the electrode axis in substantially any direction.

One object of the present invention is to provide an apparatus for generating a plasma jet and obtaining effective deflection of the generated plasma jet flowing from the apparatus.

The foregoing and other objects, features, and advantages will become apparent from the detailed description of the preferred embodiments invention as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings, which are not drawn to scale, include:

FIG. 1, which is a schematic side view diagram of one embodiment of the apparatus of the present invention having two plasma jet generator assemblies;

FIG. 2, which is a schematic top view diagram of the embodiment illustrated in FIG. 1;

FIG. 3, which is a schematic top view diagram of another embodiment of the apparatus of the present invention incorporating two plasma jet generator assemblies made in accordance with the present invention;

FIG. 4, which is a schematic top view diagram of still another embodiment of the present invention;

FIG. 5, which is a side view partial schematic diagram of the apparatus of the present invention illustrating the positioning of a plasma jet generator relative to a common axis;

FIG. 6, which is a schematic to view diagram of another embodiment of the present invention;

FIGS. 7 and 8, which are schematic diagrams of the magnetic fields; and

FIG. 9, which is a schematic top view diagram of an electrode assembly utilized in all the embodiments of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. 1, the apparatus for producing a flow of plasma comprises a plurality of plasma jet generator assemblies **5**. Referring to FIGS. 1 and 9, each plasma jet generator assembly **5** is formed from an electrically isolated closed electrode chamber **10** having a base **15** with outlet orifice **40**, gas inlet **50** and an electrode **60** positioned within the chamber **10** having an end seated in a dielectric gasket **70**. The electrode **60** forms an electrode axis **80** which extends out of the orifice **40**.

In the apparatus, a plurality of plasma jet generator assemblies **5** in multiples of two are used. The plurality of generator assemblies **5** are spatially positioned about an apparatus axis **90** and angularly positioned so that the electrode axis **80** forms angle α

with the apparatus axis **90**. The angle α is selected to be less than **90** degrees. Referring to FIG. 2, if two generator assemblies **5** are used, the generator assemblies are positioned on opposite sides of the apparatus axis **90** so that their corresponding electrode axes **80** and the apparatus axis **90** form a basic plane. Referring to FIG. 3, if four generator assemblies **5** are used, they are positioned around apparatus axis **90** with angle $\beta \cong 90°$ between their corresponding basic planes. If more than four generator assemblies **5** are used, they are located around the apparatus axis **90** with angle $\beta \cong 360°/N$ between their corresponding basic planes, where N is the quantity of generator assemblies **5**. Each of the electrodes **60** of the generator assemblies **5** are connected in pairs to a DC power supply **100**.

The generator assemblies are provided with a magnetic system made from unclosed magnetic circuits affixed to base **20**. Each unclosed magnetic circuit comprises a U-shaped member having a base **110** and a pair of poles **130** extending from the base **110**. A coil **120** is positioned about each base **110**. Each generator assembly **5** is provided with two of the unclosed magnetic circuits formed by the U-shaped member and coil. The ends **135** of the poles **130** are positioned around the electrode axes **80**. The ends **135** of each pole **130** are located in a plane which is perpendicular to the corresponding electrode axis **80**. The plane formed by the ends **135** intersects the corresponding electrode axis **80** at a position in a range between the corresponding electrode chamber orifice **40** and a point of intersection **175** between the electrode axis **80** and apparatus axis **90**. Each of the pole ends **135** is positioned from its corresponding electrode axis **80** a distance that is more than the diameter of the corresponding electrode chamber orifice **40**. The length of each of the pole ends **135** along its corresponding electrode axis **80** and the width of each of the pole ends **135** are chosen to be greater than the diameter of the corresponding electrode chamber orifice **40**. The centers of the pole ends **135** are positioned at different sides relative to the corresponding basic plane formed thereby.

Referring to FIG. 1, the apparatus may be provided with injection tube **150** having an outlet hole **162** at end **160**. The tube **150** is affixed in the base **20** and aligned with apparatus axis **90**. The distance between the end **160** of the injection tube **150** and the

point of intersection **175** of the electrode unit axes **80** and apparatus axis **90** is chosen to avoid thermal damage to the end **160** of the injection tube **150** end by heat from the adjacent plasma jets.

Referring to FIG. 4, for design simplification, each of the unclosed magnetic circuits formed by the U-shaped members may be connected to another corresponding unclosed magnetic circuit via bridge member **140**. Also, referring to FIG. 6, for design simplification, one of the poles **130** of one of first unclosed magnetic circuit of one electrode assembly may be connected with the nearest pole **130** of another unclosed magnetic circuit of the another adjoined electrode assembly. In both cases, the magnetic system has the same main external magnetic field pattern as the separated magnetic circuits, but the coils' **120** effectiveness is reduced due to the increase of side-by-side magnetic field losses of the coils. Referring to FIGS. 1 and 2, if the apparatus contains only two generator assemblies **5**, the end **160** of injection tube **150** may be provided with an opening **162** which has a dimension along the basic plane formed by the electrode axes **80** that is less than the dimension of the electrode chamber orifices **40**. Along the direction perpendicular to the basic plane formed by the electrode axes **80**, the dimension of the opening **162** may be made larger than the dimension along the basic plane. In other words, the opening **162** in the tube **150** may have an oval shape wherein the long axis of the oval is normal or perpendicular to the plane formed by the electrode axes **80**.

Referring to FIG. 4, the end **160** of the injection tube **150** may be made with a plurality of openings **162a-162e**. The plurality of openings **162a-162e** are preferably aligned along the plane normal or perpendicular to the basic plane formed by the electrode axes **80**.

Referring to FIG. 1, according to the present invention, gas is delivered into each electrode chamber **10** through gas inlet **50**, in the direction indicated by arrow A. An electrical arc discharge **170** with DC electrical current I is ignited between the electrodes **60** of each pair of electrode chambers **10** with the help of DC power supply **100**. The distance between electrode chambers **10** in every pair and angle α are chosen to provide a stable electrical discharge **170** from DC power supply **100**.

The gas flowing through the orifices **40** of the chambers **10** and electrical

discharge **170** create plasma jets **180**. The plasma jets **180** combine in mixing zone **190** to form a combined plasma flow **200**. Because of the electro magnetic interaction of the electrical currents I in the plasma jets **180**, a force F_S is applied to each of the plasma jets **180** which is directed away from the apparatus axis **90**. As a result of the application of force F_S, the plasma jets **180** bend from their initial directions along electrode axes **80** out towards the apparatus axis **90**.

An electrical current is conducted through the coil **120** of every unclosed magnetic circuit **110**. Referring to FIGS. 7 and 8, as a result of the electrical current flowing through coil **120**, an external magnetic field is created between the ends of the poles **130** of each of the unclosed magnetic circuit **110**.

Referring to FIG. 7, which looks into the apparatus axis **90**, if the electrode **60** having electrode axis **80** which is directed with an angle α that is more than 45 degrees with respect to the apparatus axis **90**, then the directions of electrical current in the coils **120** of both unclosed magnetic circuits **110** are chosen to provide external magnetic field induction vector components $\mathbf{B}_{1\perp}$ and $\mathbf{B}_{2\perp}$ that are directed perpendicular to the basic plane formed by the electrode axes **80** and the apparatus axis **90**, and are oriented along the same direction as the orientation of the corresponding plasma jet's **180** self-magnetic field induction vector $\mathbf{B}_S$, due to its current I, at the region of the basic plane between the electrode axis **80** and apparatus axis **90**. The current I of the upper electrode and the current I of the lower electrode flow in opposite directions as illustrated in FIG. 7. The external magnetic field induction vector components $\mathbf{B}_{1\perp}$ and $\mathbf{B}_{2\perp}$ create electromagnetic forces $\mathbf{F}_{1\perp}$ and $\mathbf{F}_{2\perp}$ correspondingly that are applied to the plasma jet **180** and directed away from the apparatus axis **90**. The quantity of electrical currents flowed through the coils **120** are chosen to provide a sum of forces $\mathbf{F}_{1\perp}$ and $\mathbf{F}_{2\perp}$ that is strong enough to position the plasma jet **180** at a desirable distance along the apparatus axis **90**.

Referring to FIG. 8, if the electrode **60** having axis **80** which is directed with an angle α that is less than 45 degrees between the corresponding electrode axis **80** and apparatus axis **90**, then the directions of electrical current in the coils **120** of both unclosed magnetic circuit **110** are chosen to provide external magnetic field induction vector components $\mathbf{B}_{1\perp}$ and $\mathbf{B}_{2\perp}$ that are directed perpendicular to the basic plane formed

by the electrode axes **80** and the apparatus axis **90**, are oriented along the direction which is opposite to the orientation of corresponding plasma jet **180** self-magnetic field induction vector $\mathbf{B}_S$ at the region of the basic plane between the electrode axis **80** and apparatus axis **90**. The external magnetic field induction vector components $\mathbf{B}_{1\perp}$ and $\mathbf{B}_{2\perp}$ create electromagnetic forces $\mathbf{F}_{1\perp}$ and $\mathbf{F}_{2\perp}$ correspondingly that are applied to the plasma jet **180** and directed to the apparatus axis **90**. The quantity of electrical currents flowed through the coils **120** is chosen to provide compensation of the force $\mathbf{F}_S$ by the sum of forces $\mathbf{F}_{1\perp}$ and $\mathbf{F}_{2\perp}$ to position the plasma jet **180** at a desirable distance from the apparatus axis **90**.

In both situations illustrated in FIGS. 7 and 8, due to the specific location of the pole ends **135**, the external magnetic field induction vector components $\mathbf{B}_{1//}$ and $\mathbf{B}_{2//}$, that are directed parallel to the basic plane, are oriented in opposite directions. The external magnetic field induction vector components $\mathbf{B}_{1//}$ and $\mathbf{B}_{2//}$ create electro-magnetic forces $\mathbf{F}_{1//}$ and $\mathbf{F}_{2//}$ correspondingly that are applied to the plasma jets **180**, directed perpendicular to the basic plane and oriented in opposite directions. The value and direction of the resulting force is determined by the difference between the forces $\mathbf{F}_{1//}$ and $\mathbf{F}_{2//}$. So the position of the plasma jet **180** relative to the basic plane is changed by changing the quantity of electrical currents flowing in the coils **120**.

When a combined plasma flow **200** is produced from two plasma jets **180** as illustrated in FIGS. 7 and 8, the quantity of electrical current flowing through coils **120** of the unclosed magnetic circuits **110** may be changed synchronously so that the sum of the currents is kept constant. As a result, the combined plasma flow **200** may be deflected from its initial direction along apparatus axis **90** and oscillated in the plane perpendicular to the basic plane formed by the electrode axes **80** and the apparatus axis **90**.

Referring to Fig. 1, According to the present invention, a substance **210** for treating a substrate may be injected into the combined plasma flow. The substance is injected into the combined plasma flow **200** by directing the substance at the mixing zone **190** with injection tube **150**.

As will be understood from the foregoing description, according to the present invention, several embodiments of an apparatus for generating and deflecting a plasma jet

for treating substrates has been described. It is to be understood that the embodiments described herein are merely illustrative of the principles of the invention. Various modifications may be made thereto by persons skilled in the art which will embody the principles of the invention and fall within the spirit and scope thereof. Hence, the present invention is deemed limited only by the appended claims and the reasonable interpretation thereof.

WHAT IS CLAIMED IS:

1. A plasma generator for generating and deflecting a plasma jet, the generator comprising:

an electrode chamber having a gas inlet and an outlet;

an electrode positioned within the electrode chamber, the electrode defining an electrode axis;

a first magnetic deflection system for applying a first deflecting force to a plasma flowing from the electrode chamber outlet so as to cause the plasma to flow away from the electrode axis in a first direction, the first magnetic deflection system comprising a first U-shaped member formed from a first base and a first pair of poles having ends and a first coil positioned about the base, wherein the first magnetic deflection system is positioned about the electrode chamber so that the first poles are on opposite sides of the electrode axis defined by the electrode positioned within the electrode chamber; and

a second magnetic deflection system for applying a second deflecting force to a plasma flowing from the electrode chamber outlet so as to cause the plasma to flow away from the electrode axis in a second direction, the second magnetic deflection system comprising a second U-shaped member formed from a second base and a second pair of poles having ends and a coil positioned about the base, wherein the second magnetic deflection system is positioned about the electrode chamber so that the second poles are on opposite sides of the electrode axis defined by the electrode positioned within the electrode chamber.

2. The plasma generator according to claim 1, wherein the first and second magnetic deflection systems are further positioned about the electrode chamber so that their corresponding poles are uniformly distributed around the electrode axis and so that the corresponding deflecting forces applied thereby are perpendicular to each other.

3. An apparatus for treating substrates with a plasma jet, the apparatus

comprising:

a first plasma jet generator assembly, the first assembly further comprising:

a first electrode chamber having a gas inlet and an outlet;

a first electrode positioned within the electrode chamber, the first electrode defining a first electrode axis;

a first magnetic deflection system for applying a first deflecting force to a first plasma flowing from the electrode chamber outlet so as to cause the first plasma to flow away from the first electrode axis in a first direction relative to the electrode axis, the first magnetic deflection system comprising a first U-shaped member formed from a first base and a first pair of poles having ends and a first coil positioned about the base, wherein the first magnetic deflection system is positioned about the first electrode chamber so that the first poles are on opposite sides of the first electrode axis defined by the first electrode positioned within the first electrode chamber; and

a second magnetic deflection system for applying a second deflecting force to a first plasma flowing from the electrode chamber outlet so as to cause the first plasma to flow away from the first electrode axis in a second direction relative to the first electrode axis, the second magnetic deflection system comprising a second U-shaped member formed from a second base and a second pair of poles having ends and a coil positioned about the base, wherein the second magnetic deflection system is positioned about the electrode chamber so that the second poles are on opposite sides of the first electrode axis defined by the first electrode positioned within the first electrode chamber;

a second plasma jet generator assembly, the second assembly further comprising:

a second electrode chamber having a gas inlet and an outlet;

a second electrode positioned within the second electrode chamber, the electrode defining a second electrode axis;

a third magnetic deflection system for applying a first deflecting force to a second plasma flowing from the second electrode chamber outlet so as to cause the second plasma to flow away from the second electrode axis in a first direction relative to the second electrode axis, the third magnetic deflection system comprising a third U-shaped member formed from a third base and a third pair of poles having ends and a third

coil positioned about the base, wherein the third magnetic deflection system is positioned about the second electrode chamber so that the third poles are on opposite sides of the second electrode axis defined by the second electrode positioned within the second electrode chamber; and

a fourth magnetic deflection system for applying a second deflecting force to a second plasma flowing from the second electrode chamber outlet so as to cause the second plasma to flow away from the second electrode axis in a second direction relative to the second electrode axis, the fourth magnetic deflection system comprising a fourth U-shaped member formed from a fourth base and a fourth pair of poles having ends and a coil positioned about the base, wherein the fourth magnetic deflection system is positioned about the second electrode chamber so that the fourth poles are on opposite sides of the second electrode axis defined by the second electrode positioned within the second electrode chamber; and

an injection tube for injecting a substance into a plasma jet, wherein the injection tube is positioned between the plasma jets and defines an apparatus axis.

4. The apparatus according to claim 3, wherein the first and second magnetic deflection systems are further positioned about the first electrode chamber so that their corresponding poles are uniformly distributed around the first electrode axis so that the corresponding deflecting forces applied thereby are perpendicular to each other; and wherein the third and fourth magnetic deflection systems are further positioned about the second electrode chamber so that their corresponding poles are uniformly distributed around the second electrode axis so that the corresponding deflecting forces applied thereby are perpendicular to each other.

5. The apparatus according to claim 3, wherein the first and second plasma jet generator assemblies are positioned on opposite sides of the apparatus axis, wherein the first and second electrode chambers are angled so that the first and second electrode chamber outlets point towards the apparatus axis so that the first and second electrode axis form an angle α with the apparatus axis, and wherein the first and second plasma jet

generator assemblies are positioned sufficiently close to each other to enable the first and second plasmas generated thereby to combine to form a combined plasma flow having a mixing zone.

6. The apparatus according to claim 5, wherein the angle α is greater than about 45 degrees.

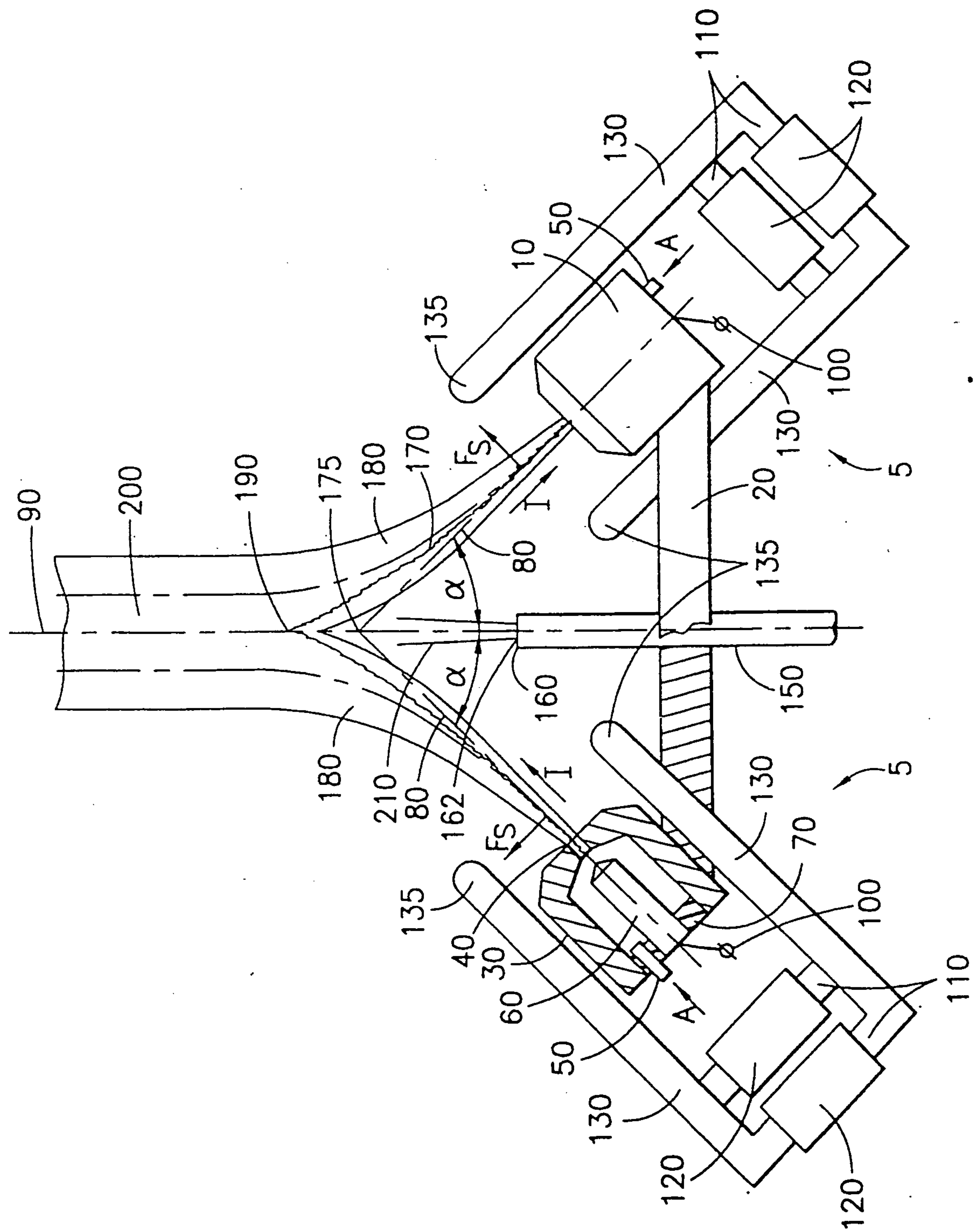
7. The apparatus according to claim 5, wherein the angle α is less than about 45 degrees.

8. The apparatus according to claim 5, wherein the angle α is about 45 degrees.

9. The apparatus according to claim 5, wherein the first and second electrode axis and the apparatus axis are aligned so as to form a common plane and wherein the deflections of the first and second plasma enable the mixing zone of the combined plasma flow to be moved along the apparatus axis and away from the apparatus axis.

10. The apparatus according to claim 9, wherein the injection tube has an oval shaped outlet, wherein the oval shaped outlet has a long axis and a short axis, and wherein the long axis of the oval shaped outlet is positioned substantially normal to the common plane.

11. The apparatus according to claim 9, wherein the injection tube has a plurality of outlets, and wherein the plurality of outlets are arranged along a line substantially normal to the common plane.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160
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210
162
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FIG. 1

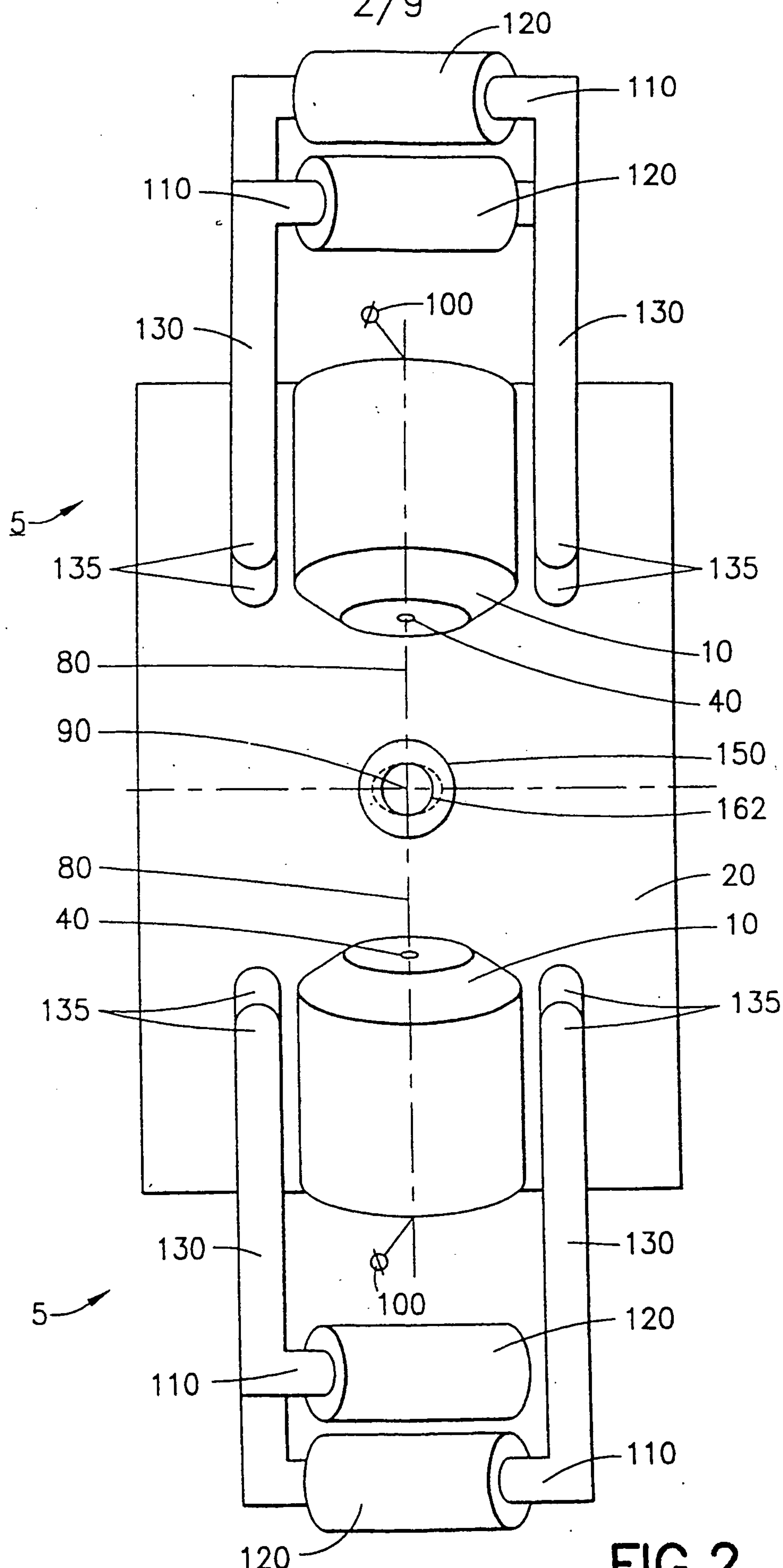
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FIG.2

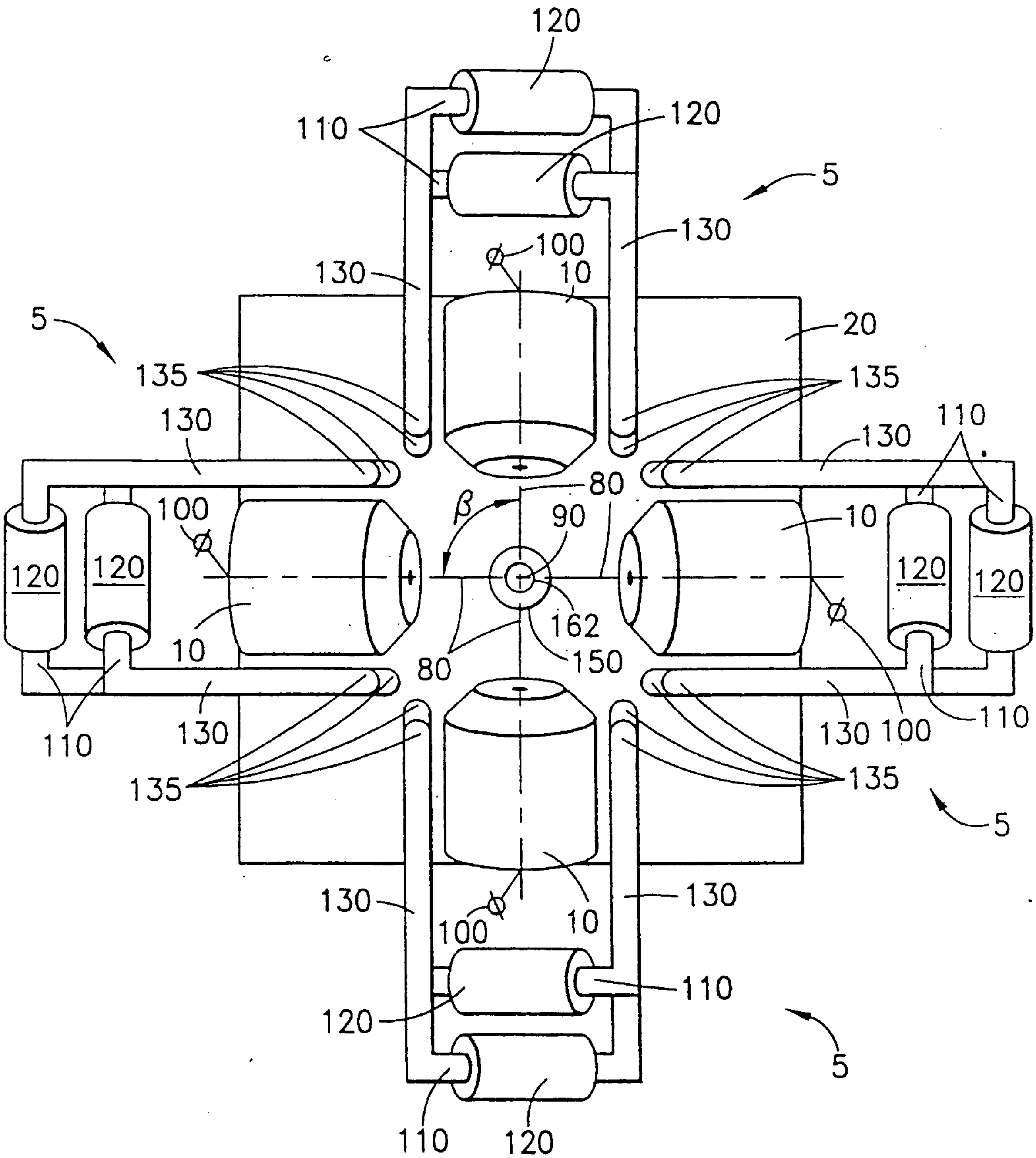
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FIG.3

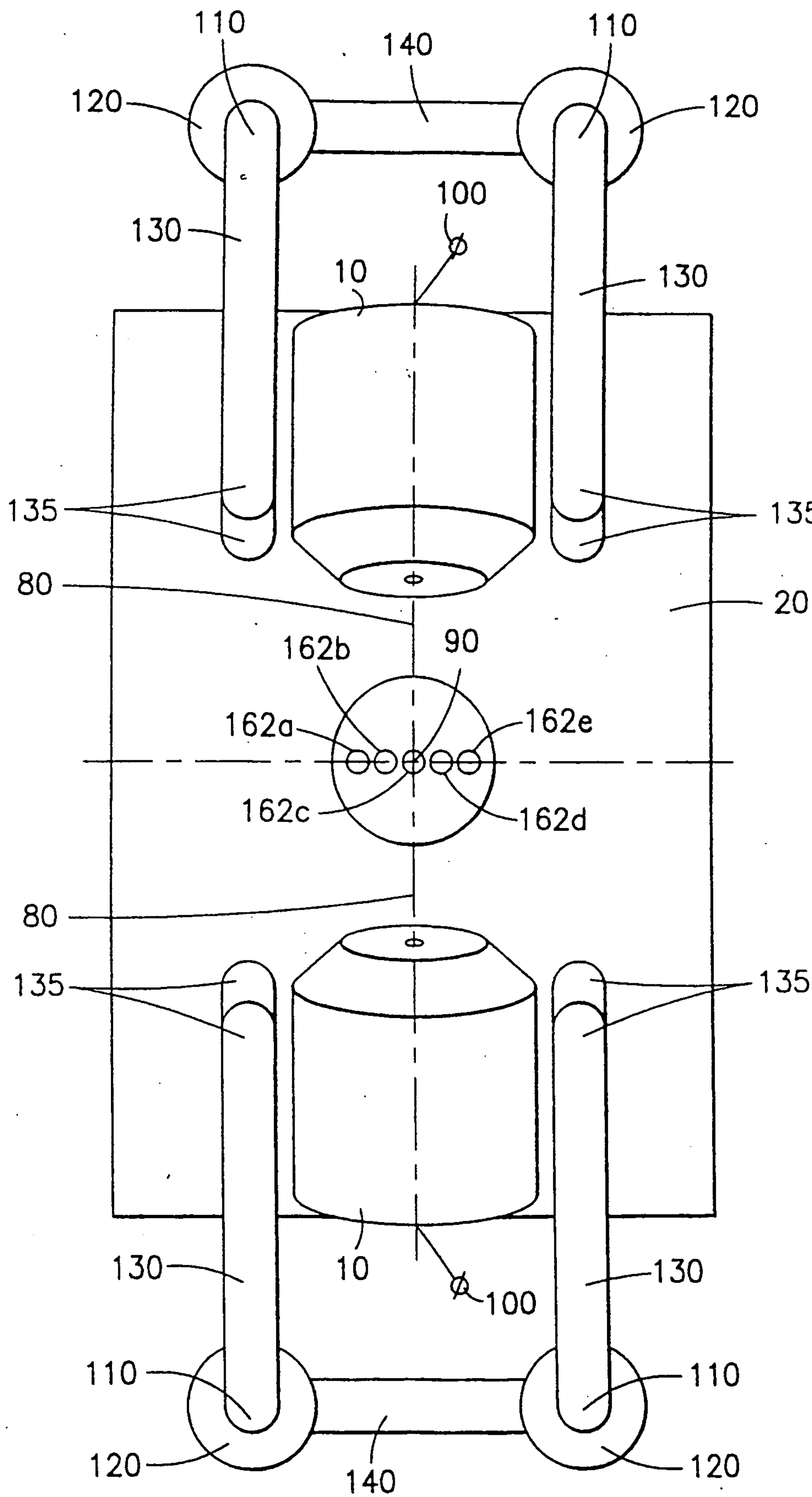
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FIG.4

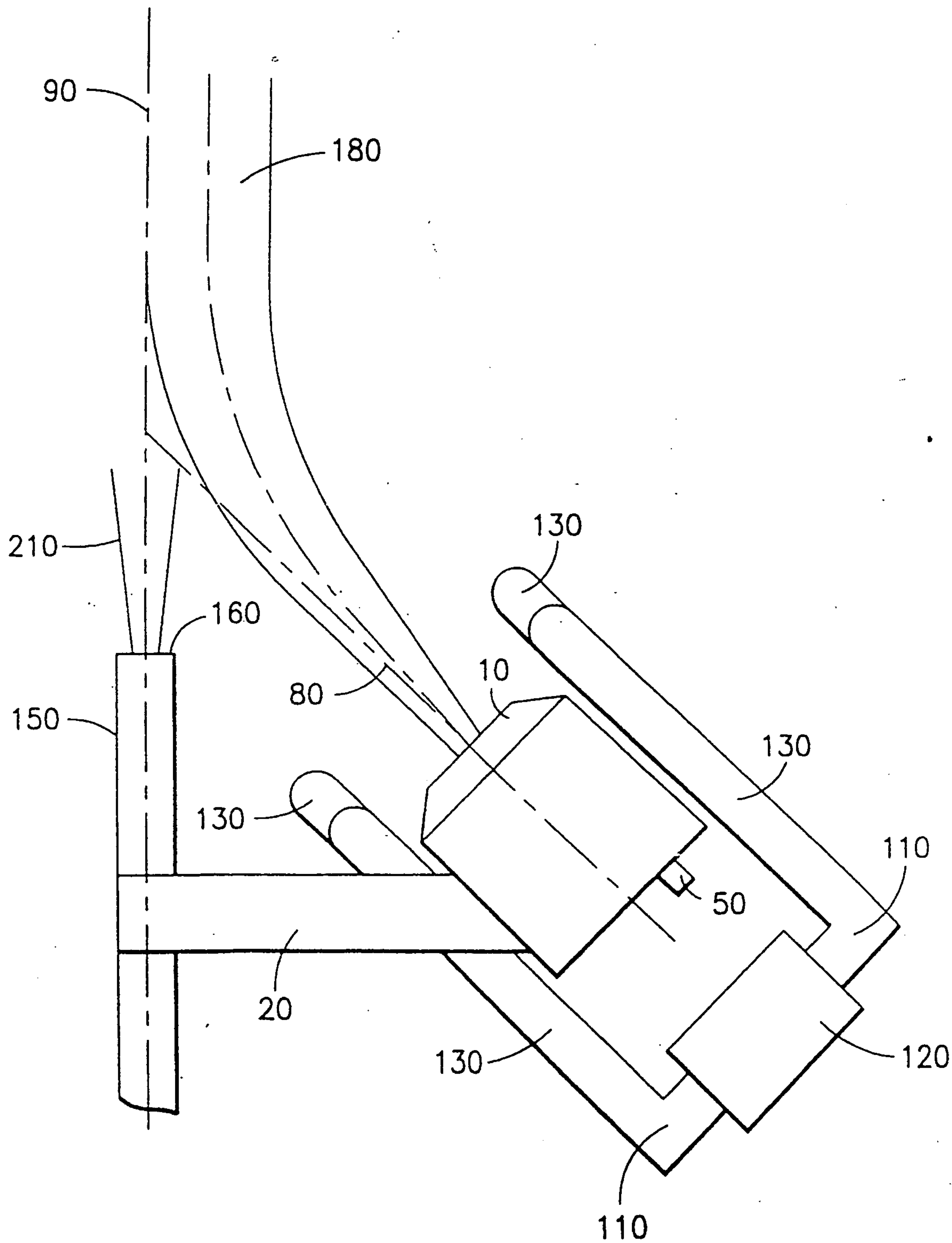

FIG.5

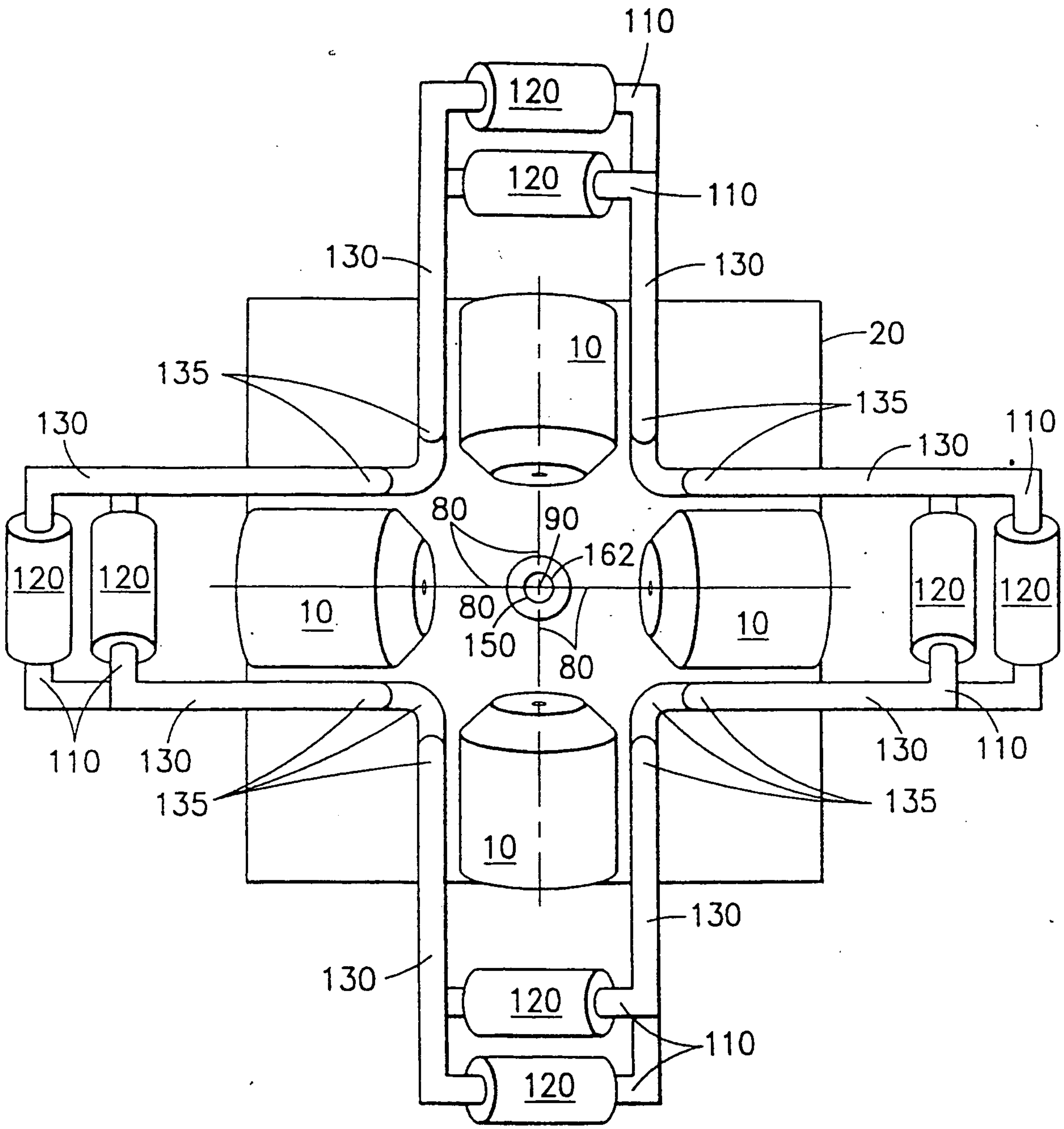
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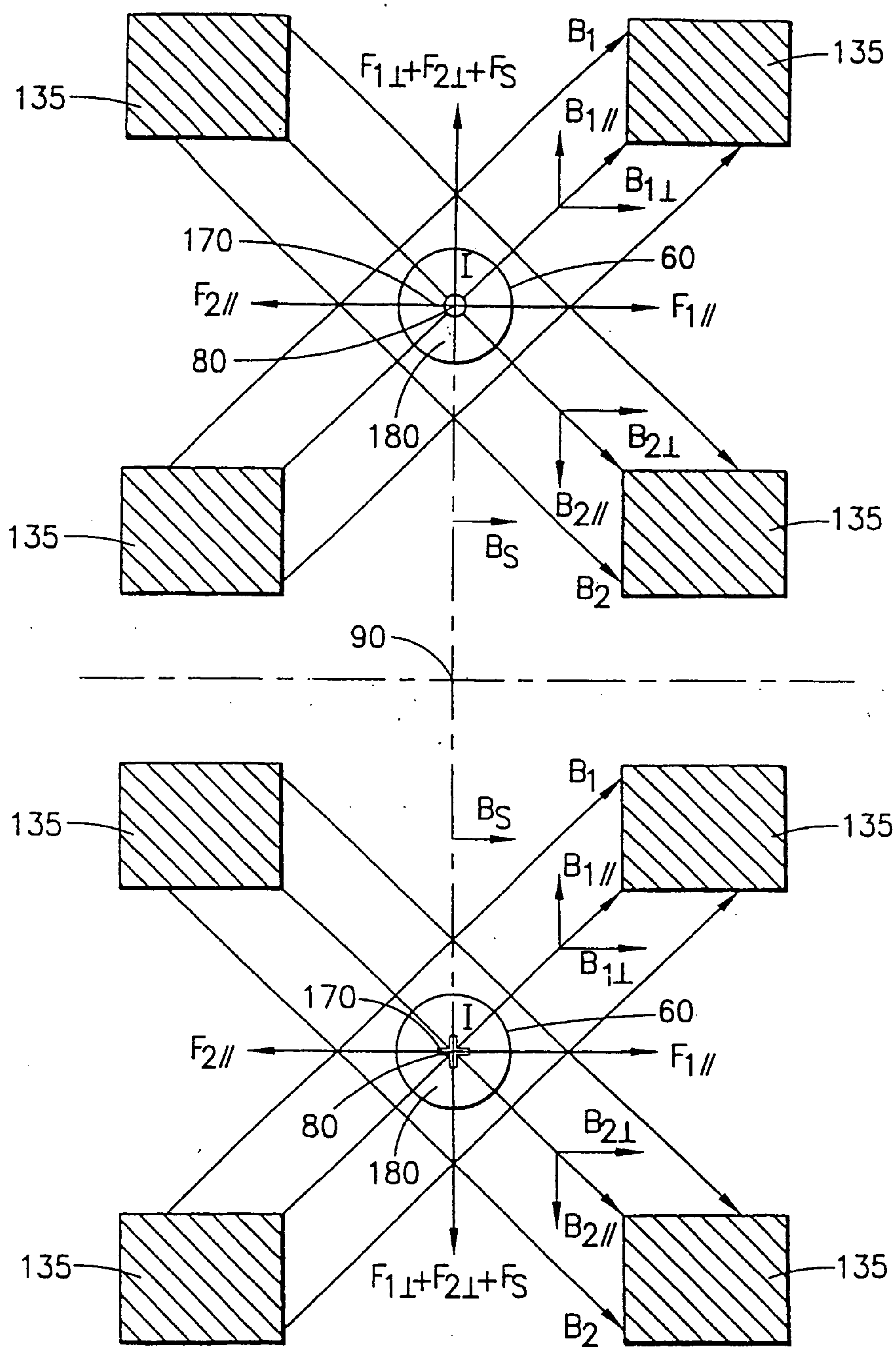
FIG.6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B_S
135
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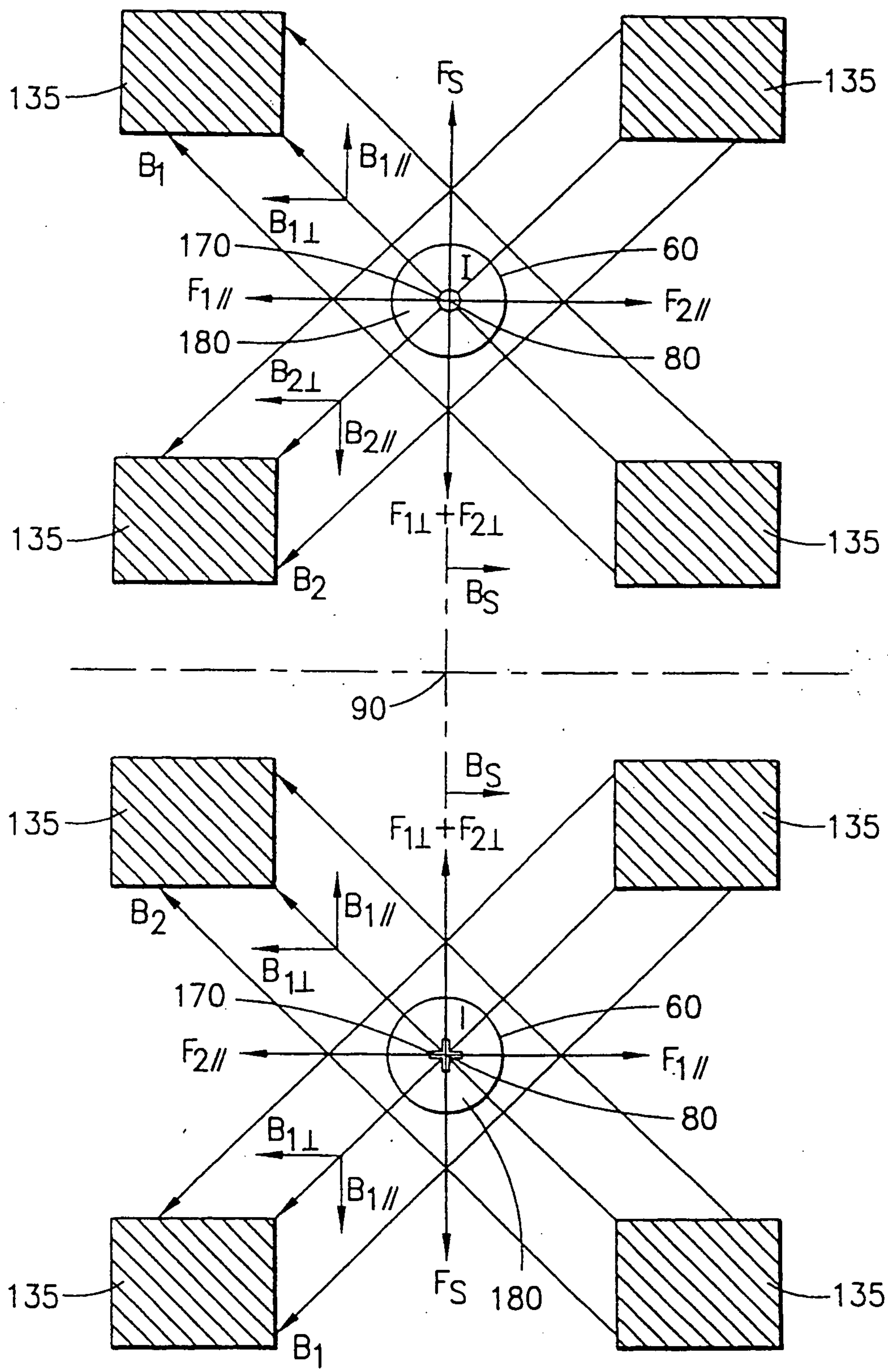
FIG.7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60
I
F1//
F2//
180
80
B2⊥
B2//
135
135
F1⊥+F2⊥
B2
BS
90
BS
135
135
F1⊥+F2⊥
B2
B1//
B1⊥
170
60
I
F2//
F1//
80
B1⊥
B1//
135
FS
180
135
B1

FIG.8

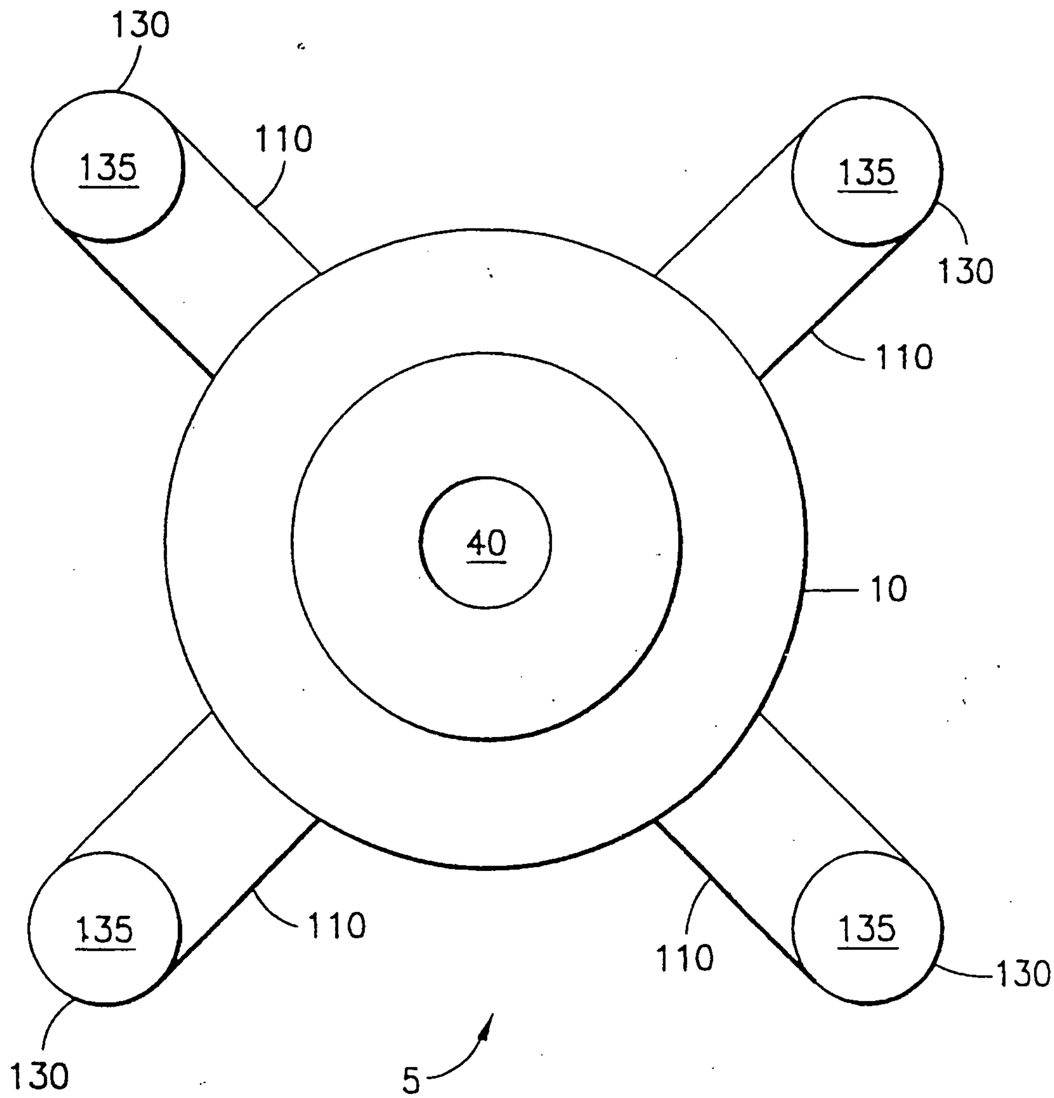

FIG.9

INTERNATIONAL SEARCH REPORT

Inten al Application No
PCT/US 97/09252

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H05H1/42 H05H1/40 H05H1/44

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H05H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DATABASE WPI Section EI, Week 9704 Derwent Publications Ltd., London, GB; Class X14, AN 97-041625 XP002041060 & RU 2 059 344 C (AZ RES PRODN STOCK CO) , 27 April 1996	1
A	see abstract; figures 1-3 ---	7
A	GB 2 271 044 A (OPA) 30 March 1994 cited in the application see page 2, line 28 - page 8, line 10 see figures 1-3 ---	1-6,9
A	US 3 453 474 A (CANN GORDON L ET AL) 1 July 1969 see column 5, line 48 - column 7, line 53 see figures 3,4 --- -/--	1-4

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 September 1997	24.09.97

1

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Capostagno, E

INTERNATIONAL SEARCH REPORT

Intern al Application No
PCT/US 97/09252

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB 2271044 A	30-03-94	WO 9212610 A	23-07-92
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		EP 0627157 A	07-12-94
		JP 7505247 T	08-06-95
		US 5489820 A	06-02-96

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 97/09252

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 93 16573 A (OPA OVERSEAS PUBLISHERS ASS AM) 19 August 1993 see page 9, last paragraph; figure 1 ---	1,3,5
A	DATABASE WPI Section EI, Week 9544 Derwent Publications Ltd., London, GB; Class X14, AN 95-343381 XP002041061 & RU 2 032 281 C (AZ RES PRODN FIRM) , 27 March 1995 cited in the application see abstract; figures -----	7